ANALYSIS OF 346 ACCIDENTS, UNDERGROUND IRON-ORE MINES, LAKE SUPERIOR DISTRICT

BY R. O. PYNNONEN, R. G. STOTT,
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SUMMARY

This circular is a study by the Bureau of Mines of 346 accidents in underground iron-ore mines of the Lake Superior district from June 1949 to August 1954. These accidents caused 354 lost-time injuries, including 28 fatalities and 2 permanent-total disabilities.

The accident reports were analyzed by the Bureau to show the causes of injuries and the time charges and unsafe practices or conditions that caused the accidents. Also shown are the times of occurrence, ages of the injured by job classification, and experience of the injured in mines and on the job being performed when hurt.

Detailed information is presented on approximately 14 percent of the total number of Lake Superior district underground mine accidents that resulted in lost-time injuries during the period covered. These facts are presented to aid accident-prevention measures in underground mines and as a record for measuring future safety accomplishments.

The text also includes tabulations and graphs showing the accident experience of the Lake Superior district underground and open-pit mines and plants from 1946 to 1954. Statistical data presented under the heading, Accident Experience, Lake Superior District Mines and Plants, were obtained from the proceedings of the annual conferences of the Lake Superior Mines Safety Council and represent the experience of an average of 24 operating companies. The statistics cover the accident experience of the district iron-ore mines and plants, a limestone quarry, and, since 1951, several copper mines in the Upper Peninsula of Michigan.

INTRODUCTION

Information on the 346 accidents presented in this circular was obtained from accident description reports submitted by eight mining companies that are members of the Lake Superior Mines Safety Council and exchange accident reports. These companies operate underground mines on the Vermilion, Mesabi, and Cuyuna iron ranges in Minnesota; the Marquette and Menominee iron ranges in Michigan; and the Gogebic iron range in Michigan and Wisconsin. Accident reports are exchanged to circulate details of the more serious or unusual accidents encountered by the participating companies. The reports follow a standard outline, and copies are sent to the Secretary of the Lake Superior Mines Safety Council for distribution to the participating members.

The number of accident reports exchanged has increased each year since the program was begun in 1944. During 1953, 19.8 percent of the underground mine accidents in the Lake Superior district that resulted in lost-time injuries were included in the accident-report exchange.

ACKNOWLEDGMENTS

The cooperation of the Executive Committee and members of the Lake Superior Mines Safety Council in furnishing information, advice, and assistance made this circular possible.

Particular acknowledgment is made to R. F. Wilson, supervisor of safety, Oliver Iron Mining Division, U. S. Steel Corp., Duluth, Minn.; Al Kolu, assistant supervisor of safety, Pickands Mather & Co., Duluth, Minn.; and E. C. Norris, Jr., formerly supervisor of industrial relations, Republic Steel Corp., Duluth, Minn., who gave valuable assistance in classifying accidents as to cause of injury. Acknowledgment also is made to the following mining companies whose accident reports are included in this circular:

The Cleveland-Cliffs Iron Co.
The M. A. Hanna Co.
Inland Steel Co.
The Montreal Mining Co.
North Range Mining Co.
Oliver Iron Mining Division of U. S. Steel Corp.
Pickands Mather & Co.
Republic Steel Corp.

GENERAL INFORMATION

The Lake Superior district is the greatest iron-ore-mining area in the world. Annual production from the district is approximately 80 percent of the tonnage mined in the United States, and shipments have averaged over 80 million long tons during the past 5 years (1950-54). Approximately 20 percent of the total production was from underground mines. Employment figures for 1953 show a total of about 7,500 underground workers at iron and copper mines in the district.

The first commercial mining in the district began with copper mining in 1844[5] on the Keweenaw Peninsula of upper Michigan. This was followed by the opening of the first iron-ore mine in 1846[6] on the Marquette range.

In response to a public demand for safer working conditions, county mine inspectors began examining mines in the district as early as 1887. By 1910, mining companies showed an increased interest in safety; some appointed safety committees, and others established full-time company safety departments. Safety engineers from several mining companies in the district met in 1912 to organize the Mining Section of the National Safety Council.

In 1919 representatives from manufacturers of safety equipment, safety engineers from 19 mining companies in the district and Federal, State, and county safety representatives formed a Lake Superior mines safety organization, which met monthly and held an annual conference.

Since that time, annual conferences have been held with attendance increasing from 65 in 1919 to 815 at the 1952 conference. Attendance at district monthly meetings during the past 5 years has ranged from 59 to 165, with an average of 106.

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[5] Van Hise, C. R., and Leith, C. K., The Geology of the Lake Superior Region: Geol. Survey Mon. 62, 1911, p. 35.

[6] Swineford, A. P., Swineford's History of the Lake Superior Iron District, Its Mines and Furnaces: Marquette Min. Jour. Office, 1871, p. 13.

Originally known as the Mining Section of the National Safety Council, the organization was renamed the Lake Superior Mines Safety Council at the 1947 annual conference in Duluth, Minn. Today's members include not only safety men but also supervisors in all capacities.

Annual accident records of the district are compiled and included in the proceedings of the annual conferences.

ACCIDENT EXPERIENCE, LAKE SUPERIOR DISTRICT MINES AND PLANTS

Accident experience in the district has compared favorably with experience in other metal-mining districts of the United States, as evidenced by reports of the Joseph A. Holmes Safety Association. National Safety Competition records show that 40 Sentinels of Safety trophies were awarded to Lake Superior district mines from 1925 to 1954 -- 20 to open-pit iron-ore mines and 20 to underground iron-ore mines.

Accident experience[7] of the open-pit mines and plants of the district and the experience at underground mines for the postwar period 1946-54 are tabulated in tables 1 and 2. Figure 1 shows graphically the accident-frequency rates and trend at underground mines for the postwar period, as compared with those of the district mines (including open-pit mines) and plants. Figure 2 compares graphically the severity rates and trend at the underground mines with those of all the district mines and plants. Figure 3 pictures the fatality rates and trend of the underground mines of the district compared with those of all the district mines and plants.

Straight-line trends of accident rates, calculated by the method of least squares, show an improvement for all mines and plants in the district as follows: 44.8 percent in accident-frequency rates, 39.4 percent in accident-severity rates, and 40.9 percent in fatality rates over the 9 years. The straight-line trends for the underground mines show an improvement of 37.8 percent in accident-frequency rates, 28.5 percent in accident-severity rates, and 29.4 percent in fatality rates for the period.

ANALYSIS OF 346 ACCIDENTS

The outline used for accident-description reports by the accident exchange group is shown in figure 4. Not all of the information on the form was given in many of the reports analyzed. Several reports omitted the time lost or charged to the injury, and nearly half of the descriptions failed to mention the amount of experience the injured had on the job he was performing when hurt. A few failed to record the age of the injured or the date or time the accident occurred. The following tabulations were based on the information that was available in the 346 underground-mine accident-description reports studied.

Classification of Causes of Injuries

Table 3 tabulates the causes of injuries. The actual or estimated time lost or charged to the accident was omitted in 17 of the 346 accident reports. The columns indicating the number injured and the total days lost or charged to injuries represent 329 accident reports in which the time lost was given, estimated, or specified. A number of accidents resulted in injuries to more than one person.

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[7] Lake Superior Mines Safety Council, Proc. Lake Superior Mines Safety Council, 1947-55.

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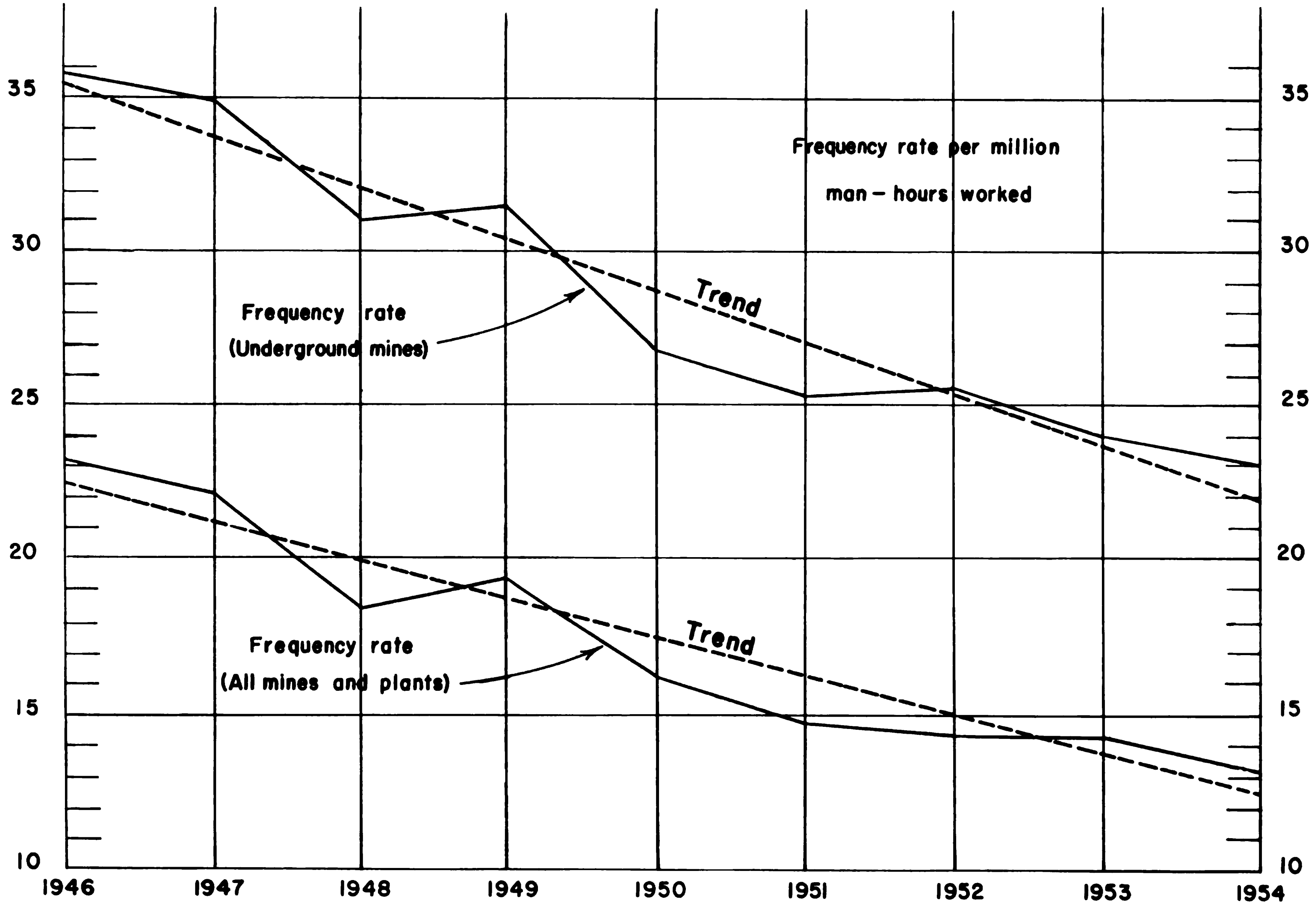

Figure 1. - Accident frequency rates and trends, Lake Superior district mines, 1946-54.

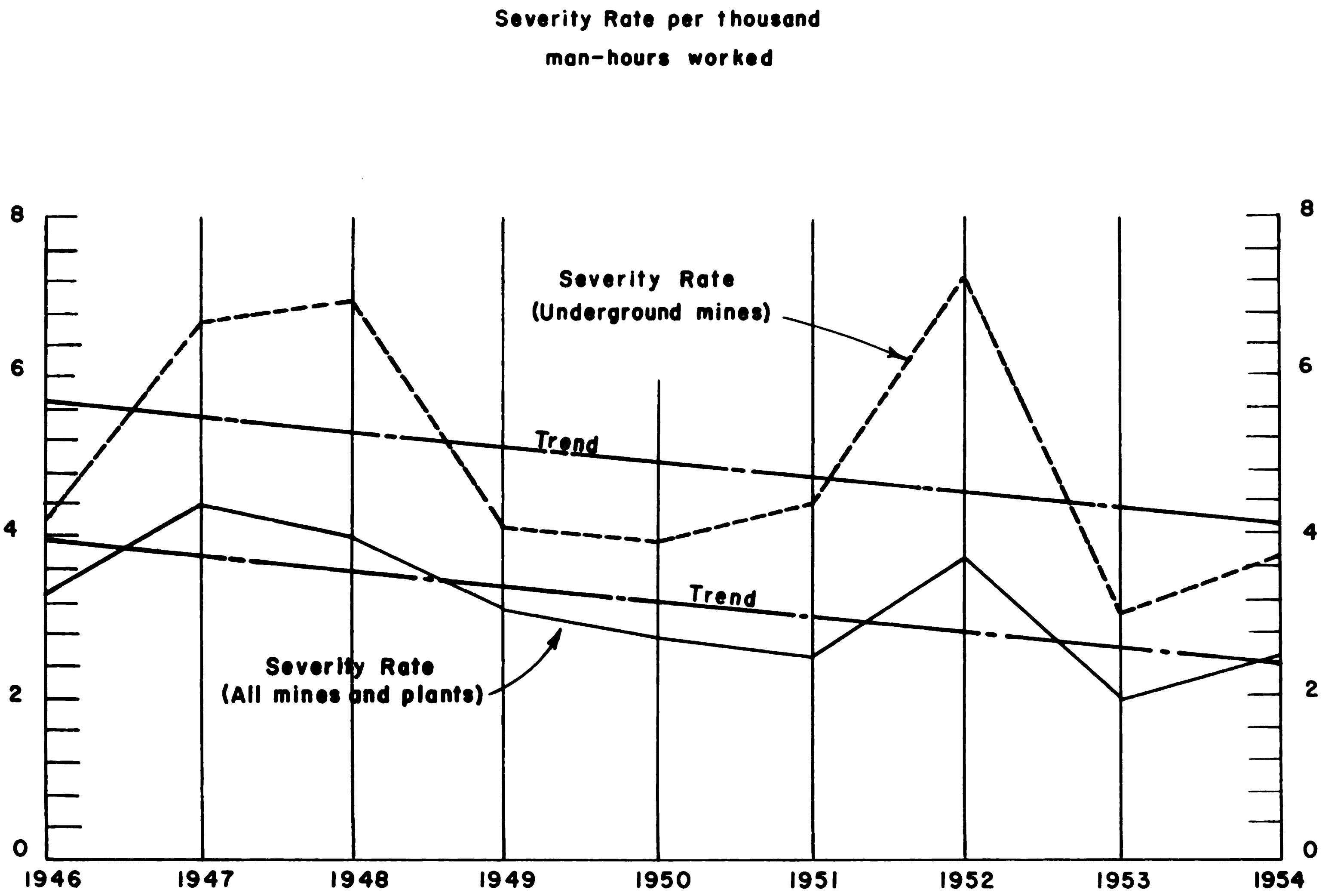

Figure 2. - Accident severity rates and trends, Lake Superior district mines, 1946-54.

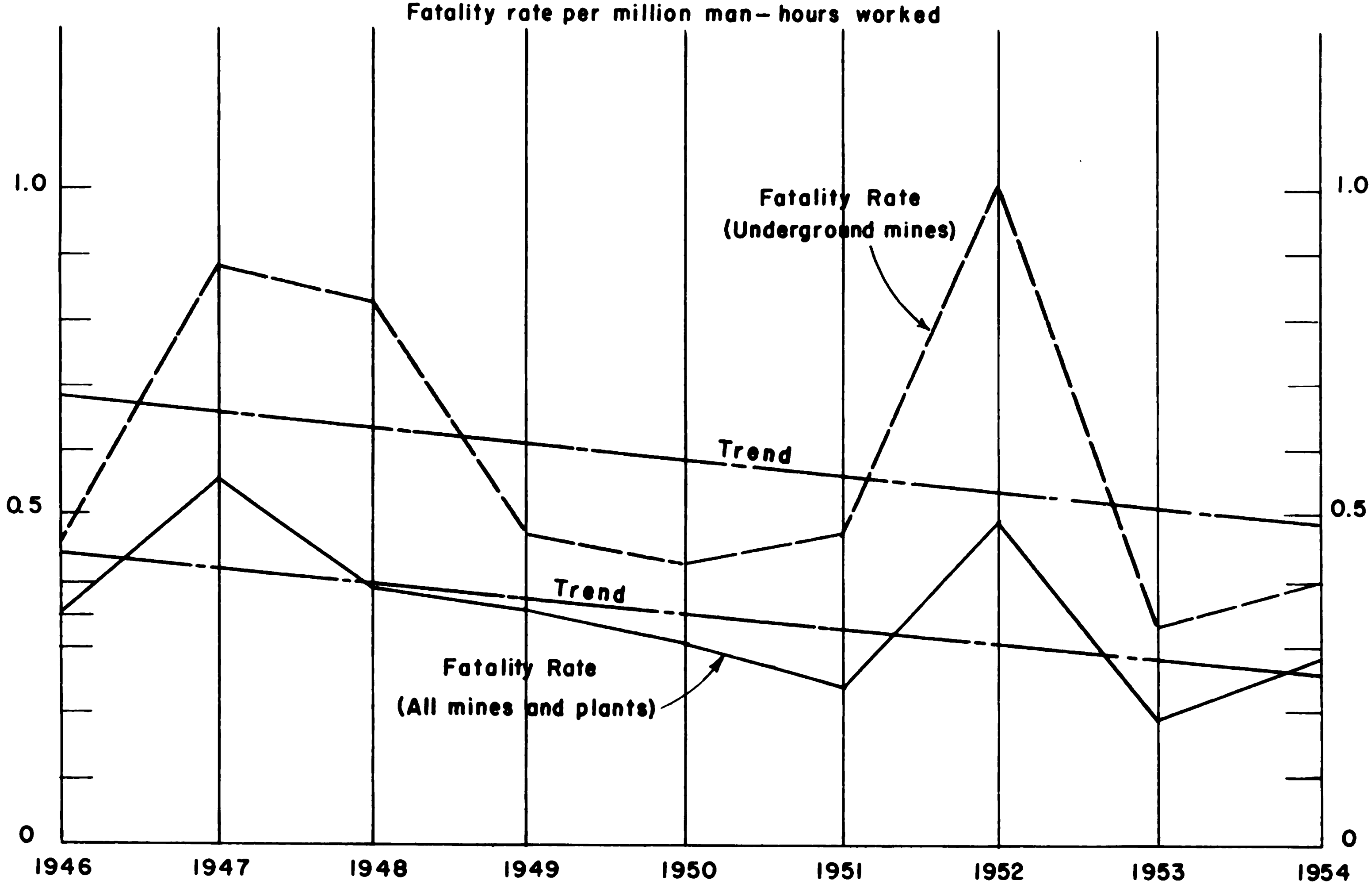

Figure 3. - Fatality rates and trends, Lake Superior district mines, 1946-54.

Underground or Open-pit mine	State	Year

INTRODUCTION:

Occupation of injured, age, injury received, date, time, what injured was doing.
Marital status and number of dependents.
Length of time employed by company, ALSO
- (a) total years employed in mines, if known
- (b) total years experience at job on which injured

NATURE AND EXTENT OF INJURY:

Description of injury.
Time lost -
- (a) temporary disability - actual or estimated calendar days
- (b) Permanent partial or total disability - days charged from scale

CAUSE OF INJURY:

Describe immediate cause of injury - examples: (1) hit on hand by falling rock, (2) particle of steel pierced eye, (3) fell off truck, or (4) pinned against timber by derailed car, etc.........

CAUSE OF ACCIDENT:

Unsafe acts or practices - itemize briefly
Unsafe conditions, equipment or tools

PHYSICAL FACTORS INVOLVED:

Describe briefly - tools or equipment being used, material being handled, operation being performed, physical conditions

DESCRIPTION OF ACCIDENT:

Exactly what injured was doing immediately prior to accident.
What happened to cause the accident and injury
What did injured or someone else do or not do to cause accident and injury.
Was accident reported immediately and what medical attention was given.

CONCLUSIONS:

What safety violation was involved: unsafe acts or practices, conditions, or equipment, lack of use of personal protective equipment, etc....

What should have been done differently to avoid accident?

Were conditions contributing to accident usual or unusual, i. e.
- (a) does same job always involve some degree of hazard, or
- (b) were conditions at time of accident unusual, and if so, why?

RECOMMENDATIONS:

List recommendations to prevent recurrence of similar accidents, if you think the recommendations will be valuable to some other person or company.

Figure 4. - Accident description report form.

TABLE 1. - Accident experience, Lake Superior district mines and plants, 1946-54

Year	No. of companies	Total hours worked	No. of lost-time injuries	No. of days lost or charged	No. of[1] fatalities	Frequency rate	Severity rate[2]	Fatality rate
1946	23	32,963,546	765	109,760	12	23.21	3.33	0.36
1947	21	43,039,615	951	188,797	24	22.10	4.39	.56
1948	24	48,258,544	891	190,920	19	18.46	3.96	.39
1949	26	44,074,032	852	136,674	16	19.33	3.10	.36
1950	24	48,214,117	784	133,341	15	16.26	2.77	.31
1951	24	61,974,377	921	154,838	15	14.86	2.50	.24
1952	23	57,226,778	824	212,779	28	14.40	3.72	.49
1953	28	64,571,876	929	127,598	12	14.38	1.98	.19
1954	26	50,529,229	673	127,283	14	13.32	2.52	.28
Average	24	50,094,679	843	153,554	17	16.83	3.07	0.34

[1] Includes permanent total disabilities.
[2] Severity rates computed on basis of days lost per thousand man-hours worked.

TABLE 2. - Accident experience, underground mines, Lake Superior district, 1946-54

Year	No. of companies	Total hours worked	No. of lost-time injuries	No. of days lost or charged	No. of[1] fatalities	Frequency rate	Severity rate[2]	Fatality rate
1946	9	15,658,129	561	65,928	7	35.83	4.21	0.45
1947	9	20,470,438	714	136,720	18	34.88	6.68	.88
1948	9	21,726,089	675	150,824	18	31.07	6.94	.83
1949	9	19,040,056	601	78,406	9	31.57	4.12	.47
1950	9	20,776,124	557	80,909	9	26.81	3.89	.43
1951	9	25,271,532	639	109,812	12	25.29	4.35	.47
1952	9	22,822,743	584	164,791	23	25.59	7.22	1.01
1953	9	23,982,106	577	73,071	8	24.06	3.05	.33
1954	9	20,223,128	468	74,349	8	23.14	3.68	.40
Average	9	21,107,816	597	103,868	12	28.28	4.92	0.59

[1] Includes permanent total disabilities.
[2] Severity rates computed on basis of days lost per thousand man-hours worked.

TABLE 3. - Classification of causes of injuries

Cause of injury	No. of accidents	Percent of total accidents	No. of fatalities[1]	Percent of total fatalities[1]	No. injured[2]	Total days lost or charged[2]	Percent of total days charged	Ave. no. of days lost per injury
Falls and slides of ground............	73	21.1	10	33.3	68	60,219	29.7	886
Hoisting and haulage..	50	14.5	8	26.8	47	51,577	25.4	1,097
Falling, slipping, and stumbling..........	46	13.3	3	10.0	45	20,638	10.1	459
Handling materials....	46	13.3	0	-	41	2,495	1.2	61
Loading and loading equipment..........	24	6.9	0	-	24	2,380	1.2	99
Falling objects.......	17	4.9	1	3.3	17	6,448	3.2	379
Flying objects........	16	4.6	0	-	15	5,543	2.7	370
Drilling and drilling equipment..........	15	4.3	0	-	14	378	.2	27
Falling and rolling chunks............	15	4.3	0	-	14	1,138	.6	81
Hand tools............	12	3.5	0	-	12	416	.2	35
Explosives............	9	2.6	6	20.0	16	37,411	18.4	2,338
Moving machinery......	9	2.6	0	-	9	1,859	.9	207
Electricity...........	4	1.2	1	3.3	3	6,037	3.0	2,012
Other.................	10	2.9	1	3.3	11	6,452	3.2	587
Total	346	100.0	30	100.0	336	202,991	100.0	604

1/ Includes permanent total disabilities.

2/ Does not include 17 accidents in which the report fails to give time lost, charged, or estimated lost as result of injury.

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In calculating the figures for Average number of days lost per injury, the total days lost or charged was divided by the corresponding figure in the Number injured column.

Falls of ground was the leading cause of injuries, followed closely by hoisting and haulage accidents. Together, they composed 35.6 percent of the 346 accidents, 60 percent of the fatalities and permanent total disabilities, and 55.1 percent of the total time lost or charged to injuries.

The third leading cause of injuries was falling, slipping, and stumbling, which composed 13.3 percent of the accidents, 10 percent of the fatalities, and 10.1 percent of the time lost or charged to injuries.

Injuries from explosives ranked highest in severity and were followed by those from electricity and from hoisting and haulage, respectively.

Unsafe Practices and Unsafe Conditions

Unsafe practices were construed to mean those acts or practices that could normally be controlled and that deviated from accepted safe practices. Unsafe conditions were interpreted as hazardous conditions, created by man or nature, that the injured person or persons had no ordinary means of knowing or controlling.

Five accidents, including one fatality, could not be classified under unsafe practices or unsafe conditions.

Study of the remaining 341 accidents revealed that: (1) 253 accidents (74.2 percent of the total) were caused solely by unsafe practices, resulting in 16 of the 29 fatalities and permanent total disabilities; (2) 32 accidents (9.4 percent of the total) were caused solely by unsafe conditions, resulting in 4 fatalities; and (3) 56 (16.4 percent of the total) were caused by a combination of unsafe practices and unsafe conditions, resulting in 9 fatalities or permanent total disabilities.

Table 4 lists the unsafe practices contributing to the causes of 309 accidents, 253 caused by unsafe practices and 56 caused by a combination of unsafe practices and unsafe conditions. In 60 percent of the cases 2 to 4 unsafe practices contributed to the accident. There were 466 occasions of the unsafe practices listed in table 4 that contributed to the 309 accidents. In tabulating the number of fatalities in which the accident was the result of a combination of unsafe practices the fatality was listed once opposite the primary unsafe practice causing the injury.

Failure to follow instructions or established procedures was the most frequent unsafe practice (23.2 percent of the occasions listed) and resulted in 41.4 percent of the fatalities and permanent total disabilities. Unnecessary exposure to danger and failure to correct known hazards were next in frequency (30.4 percent of the total unsafe practices listed) and resulted in 27.5 percent of the fatalities and permanent total disabilities.

Table 5 lists the unsafe conditions contributing to 88 accidents, 32 caused by unsafe conditions and 56 by a combination of unsafe practices and conditions. In 6 instances 2 unsafe conditions contributed to the same accident. Altogether there were 94 occasions of the unsafe conditions listed in table 5.

TABLE 4. - List of unsafe practices contributing to 309 accidents

Unsafe practices	No. of occasions	Percent of total occasions	No. of fatalities	Percent of total (29) fatalities
1. Failure to follow instructions or established procedures..	108	23.2	12	41.4
2. Unnecessary exposure to danger..........................	81	17.3	5	17.2
3. Failure to correct known hazards........................	61	13.1	3	10.3
4. Failure to properly inspect working place or equipment....	39	8.4	0	-
5. Failure to be alert or exercise caution.................	39	8.4	1	3.4
6. Failure to wear protective clothing or equipment.........	22	4.7	3	10.3
7. Inadequate or faulty supervision or training............	19	4.1	1	3.4
8. Failure to use proper tools or to obtain help when needed.	19	4.1	0	-
9. Lack of coordination between employees..................	18	3.9	0	-
10. Failure to replace or use guards........................	14	3.0	0	-
11. Unnecessary haste, taking shortcuts, etc.................	12	2.6	0	-
12. Other...	34	7.2	0	-
Totals..	466	100.0	25	86.0

Note: 9 of the above-listed fatalities involved both unsafe practices and unsafe conditions.

TABLE 5. - List of unsafe conditions contributing to 88 accidents

Unsafe conditions	No. of occasions	Percent of total occasions	No. of fatalities	Percent of total (29) fatalities
1. Defective equipment or failure of equipment....	24	25.6	2	6.9
2. Loose ground, too extensive to detect..........	9	9.6	5	17.2
3. Lack of guards or safety devices...............	9	9.6	2	6.9
4. Unsafe footing not controllable by employees...	8	8.5	0	-
5. Unsafe timber...................................	7	7.4	0	-
6. "Hung" mill or chute............................	7	7.4	0	-
7. Insecure ladders, grizzlies, or equipment......	7	7.4	2	6.9
8. Insufficient clearance..........................	6	6.4	1	3.4
9. Poor visibility.................................	3	3.2	1	3.4
10. Defective materials............................	3	3.2	0	-
11. Other..	11	11.7	0	-
Total	94	100.0	13	44.7

Note: 9 of the above-listed fatalities involved both unsafe conditions and unsafe practices.

Defective equipment and equipment failure was the most frequent unsafe condition; however, loose ground too extensive to detect was responsible for 17.2 percent of the fatalities.

Time of Occurrence

The time of accident occurrence was reported in 287 of the 346 accident-description reports. The hour of occurrence is shown in figure 5, with the shift changes indicated. Approximately 50 percent of the accidents occurred on the day shift, when the mine crews were the largest.

Figure 5 shows that accident frequency reached a peak during the second hour of the day and afternoon shifts. Accident frequency was high 2 to 3 hours before the end of these shifts also. Normally, these hours are the most productive periods for the miners. Approximately 53 percent of the accidents on the day and afternoon shifts occurred during these hours. Fifty-one accidents were recorded on the midnight shift, 33, or approximately 65 percent, occurred from 1 to 5 a.m.

The chart also indicates fewer accidents during the hours when shifts are changing and at lunch times. A total of 104 accidents (36.2 percent of the total in which time was reported) occurred from 9 to 10 a.m., 1 to 3 p.m., and 5 to 6 p.m. Only 15 accidents (5.2 percent) occurred between 5 to 7 a.m. and 11 p.m. to 1 a.m.

Ages of Injured, by Job Classification

Table 6 lists the injured, by job classification, and the average age for each group. The table lists only those injuries for which the age of the employee was reported.

TABLE 6. - Average age of injured, by job classification

Job classification	Number injured[1]	Percent of total injured	Average age of injured
Miners	209	61.9	40.5
Haulagemen	49	14.5	45.3
Repairmen	26	7.7	50.7
Landers, cage and skip tenders, station attendants	15	4.4	44.7
Mechanics and pipemen	14	4.1	41.3
Supervisors	8	2.4	44.5
Others: Electricians, carpenters, pumpmen, painters, etc.	17	5.0	46.6
Total	338	100.0	42.5

[1] Number of injured for which age was reported.

Total Experience of Injured in Mines

Table 7 lists the total experience of the injured, by job classification, and covers 227 injuries for which the experience was reported. It is significant that 53.4 percent of the injured had more than 10 years' experience in underground mines. Approximately 20 percent of the injured has less than 2 years' experience in the mines.

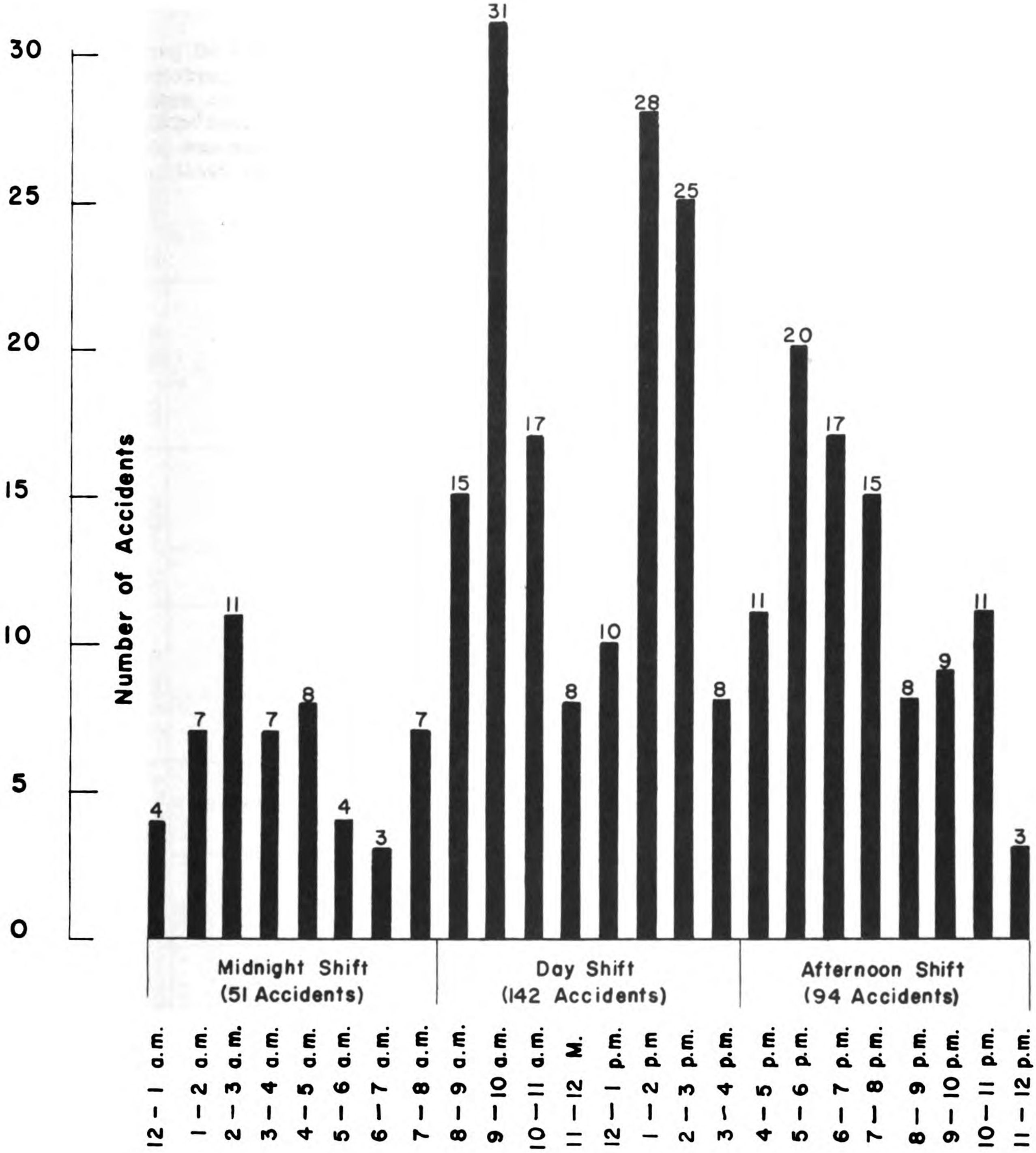

Figure 5. - Accident occurrence by time of day, 287 accidents.

Experience of Injured On the Job

On-the-job experience is classified in table 8. Approximately 40 percent of the injured had less than 2 years' experience on the job they were performing when injured, which might indicate the need for more thorough training for employees assigned new jobs. This, plus the relatively small number of injured with less than 2 years' total experience in mines, might indicate that supervisors are placing too much emphasis on total experience in mines in lieu of adequate job training.

TABLE 7. - Total experience of injured in mines

Job classification	Less than 1 year	1 to 2 years	More than 2 years but less than 5 years	More than 5 years but less than 10 years	More than 10 years but less than 20 years	More than 20 years	Total
Miners.................	13	3	19	23	15	40	113
Haulagemen.............	14	3	4	2	7	16	46
Repairmen (timberman).........	1	1	2	3	5	10	22
Landers, skip and cage tenders, and station attendants..........	1	1	1	0	2	1	6
Mechanics and pipemen..	1	3	1	1	2	2	10
Supervisors............	0	0	1	0	2	3	6
Others.................	3	2	1	2	8	8	24
Total	33	13	29	31	41	80	227
Percent of total	14.5	5.7	12.8	13.6	18.1	35.3	100.0

TABLE 8. - Experience of injured on the job

Job classification	Less than 1 year	1 to 2 years	More than 2 years but less than 5 years	More than 5 years but less than 10 years	More than 10 years but less than 20 years	More than 20 years	Total
Miners.................	32	14	25	23	16	17	127
Haulagemen.............	16	2	6	6	2	5	37
Repairmen (timbermen).........	4	4	1	3	4	1	17
Landers, skip and cage tenders, and station attendants..........	4	2	4	1	1	0	12
Mechanics and pipemen..	2	2	3	3	0	0	10
Supervisors............	1	0	1	2	0	2	6
Others.................	7	2	3	4	4	2	22
Total	66	26	43	42	27	27	231
Percent of total	28.6	11.2	18.6	18.2	11.7	11.7	100.0